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# Washington Metro: Planning for Growth

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# Washington Metro: Planning for Growth

## **Abstract**

In 1966, the United States Congress created the Washington Metropolitan Area Transit Authority (WMATA) to take control of the District's private bus system and develop a new Metro network for the Nation's capital. Following extensive planning, construction of Washington's Metrorail transit system started in 1969. Seven years later, revenue service began on a 7-kilometre line section with five stations in operation. Another 25 years later, in 2001, the originally planned Washington Metrorail system, shown in Figure 1, was completed, reaching a total of 166 kilometres with 83 stations.

## **Disciplines**

Engineering | Systems Engineering | Transportation Engineering

# Washington Metro: Planning for growth

► VUKAN R. VUCHIC AND  
JEFFREY M. CASELLO

In 1966, the United States Congress created the Washington Metropolitan Area Transit Authority (WMATA) to take control of the District's private bus system and develop a new Metro network for the Nation's capital. Following extensive planning, construction of Washington's Metrorail transit system started in 1969. Seven years later, revenue service began on

several billion dollars. Many suburban centres in Maryland and Virginia have also been created around Metro stations. Business persons, visitors and tourists use the Metro extensively. The city and its surroundings have become much more economically viable and liveable since the Metro's opening.

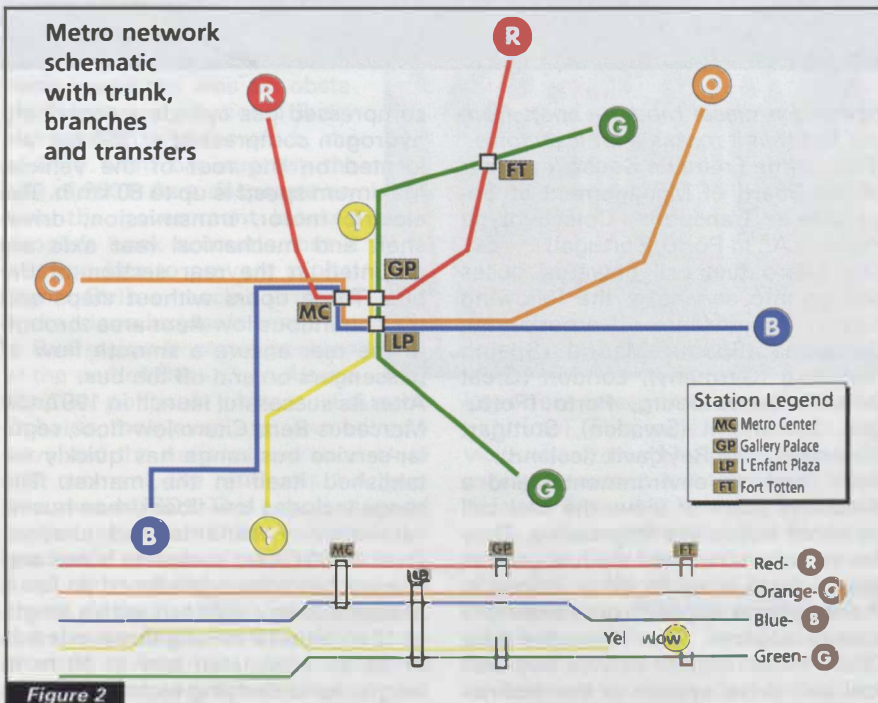
Metro's popularity is demonstrated by its ridership, with average weekday trips exceeding 600,000. With strong population and employment gains

Francisco BART, Atlanta, Miami, Baltimore, Los Angeles), the Washington Metrorail system can best be defined as a combination of urban metro and regional rail system. All lines serve city-centre and surrounding high-density areas and then extend diametrically to rather distant suburbs. For example, the core Red line central section of 7.4 kilometres extends 16.5 kilometres to the north east (Glenmont) and 23.9 kilometres to the north west (Shady Grove), totalling 47.8 kilometres in length. Similarly, the system's Orange line reaches 19.5 kilometres westwards to the town of Vienna in Virginia. Thus, the system resembles much more the RER than Metro in Paris; it is more similar to the S-Bahn than U-Bahn networks in German cities.

By its operation, however, the Washington system is an urban metro, rather than a regional rail system. The metro line sections comprise 80 kilometres of subways, 15 kilometres of aerial structures, and 71 kilometres' at grade tracks. Metro's rolling stock consists of 762 vehicles, operating in four- and six-coach trains, using either manual or automatic driving. Service headways range from 2.5 minutes in the peaks to 20 minutes during late evening hours. Top running speeds on the system are 95 km/h.

Passenger access modes vary by station location. central stations rely heavily on pedestrian access, as well as co-ordinated bus services. In outlying areas, the feeder function is performed by buses, and even more so, by a North-American speciality: Kiss-and-Ride and Park-and-Ride. Of Metro's current 83 stations, 34 provide Park-and-Ride facilities; in some cases, the demand for P+R is such that multi-story parking garages have been built. In total, the Metrorail system offers more than 33,000 parking spaces for its users, most of them for a USD2 daily fee.

The Metrorail system has connections to several other modes and carriers. For example, its Blue and Yellow Lines serve Reagan National Airport, while the Red Line includes Union Station, providing a direct connection to Amtrak intercity rail service. Metro also



a 7-kilometre line section with five stations in operation. Another 25 years later, in 2001, the originally planned Washington Metrorail system, shown in Figure 1, was completed, reaching a total of 166 kilometres with 83 stations.

## Metro growth since its opening

The Washington Metro has been an outstanding success. It immediately generated much higher ridership than the bus system, created new inner-city trips and changed the city's image. Investment in new buildings in Washington's central city, stimulated by Metro's presence, has amounted to

forecast for the Washington area, ridership is projected to increase on existing lines, and new transit markets have potential to generate additional passengers. WMATA is therefore evaluating the network operation and form, as well as the system capacity through the network's 'core' area. This article briefly describes two studies: a capacity analysis of the Metro network's core portion, and the possible system extensions in both the city and suburbs.

## Network form and character

Similar to the metro systems built in other US cities in recent decades (San



# System Map

## Legend

- Red Line • Glenmont to Shady Grove
- Orange Line • New Carrollton to Vienna/Fairfax-GMU
- Blue Line • Franconia-Springfield to Largo Town Center
- Green Line • Branch Avenue to Greenbelt
- Yellow Line • Huntington to Mt Vernon Sq/7th St-Convention Center

Station in Service  
 Virginia Railway Express  
 Commuter Rail  
 MRC  
 Transfer Station  
 Planned Station  
 Parking



Figure 1

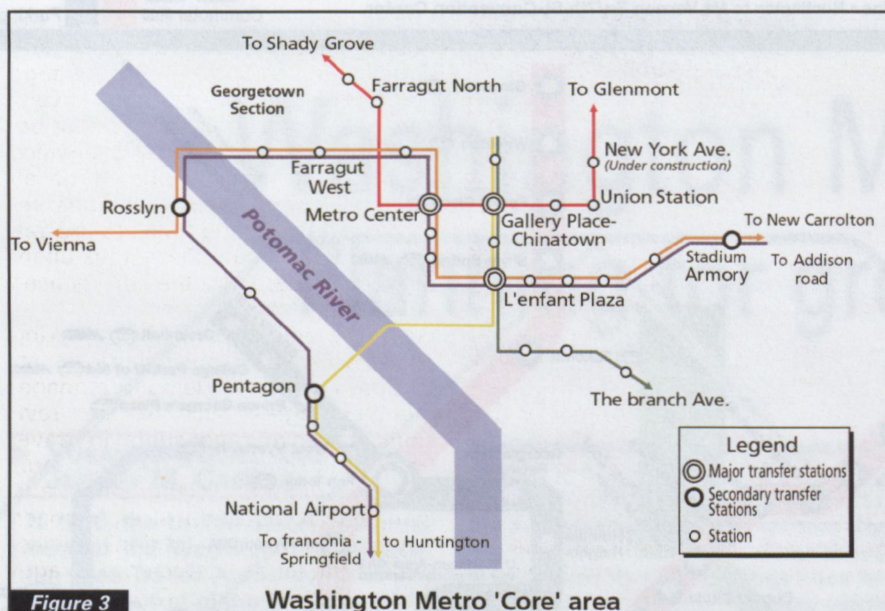
has several joint stations with Maryland's (MARC) and northern Virginia's (VRE) regional rail systems. The Metro network consists of four diametrical lines connecting outlying suburbs through the central area, and one radial line serving the city centre and a southern corridor. The Red line is a single, independent line; the Blue and Orange lines share a joint trunk, as do the Green and Yellow lines. On their southern sections, the Yellow and Blue Lines join and then branch out again. Figure 2 gives a schematic

representation of the Metro network's trunks, branches and transfer points. This type of interconnected network is more complex to operate than independent lines, but it offers more options for routing and adjusting services to special conditions. With many national civic events in Washington, Metro must often provide high capacity services for surges in passenger demand at short notice.

**Planning for further growth**  
 In 1999, the WMATA Board outlined

its vision for the Metro system development until the year 2025. To maintain regional mobility, the Board concluded that Metro must serve ridership two times greater than at present. To plan for that requirement, two studies were undertaken. The first evaluation determined the capacity of the network through its core section; the second planned necessary capacity enhancements, including the construction of new stations, branches and lines.





### Core capacity analysis

The 'Core Capacity Study' was undertaken to evaluate the system's capability to accommodate the increased ridership levels. Specifically, the study comprehensively examined the capacity of the three lines' trunk sections, shown in Figure 3. Because 'bottlenecks' in Metro operation may occur along the line or at stations (on platforms, escalators, at fare collection gates etc.), a comprehensive systems approach was needed to evaluate system capacity. For each Metro line, two capacities were defined and evaluated: line (train carrying) capacity and station (access) capacity.

**Line capacity**, or the maximum passenger volume trains can carry per hour, is determined by the line design elements and operating conditions, such as track alignment, signals, the capacity of trains, their utilisation and station operations. During peak hours, Metro currently operates six-car trains, with a policy load of 120 persons per car, and minimum headways of 2.5 minutes. This results in a current line capacity of 17,280 persons per hour.

Using 2025 station-to-station ridership figures, developed by the region's planning organisation, new Maximum Load Sections were identified for each Metro line. The projected 2025 passenger volumes exceed present capacity on all lines, in some cases by more than 100%. Therefore, major capacity increases will be necessary.

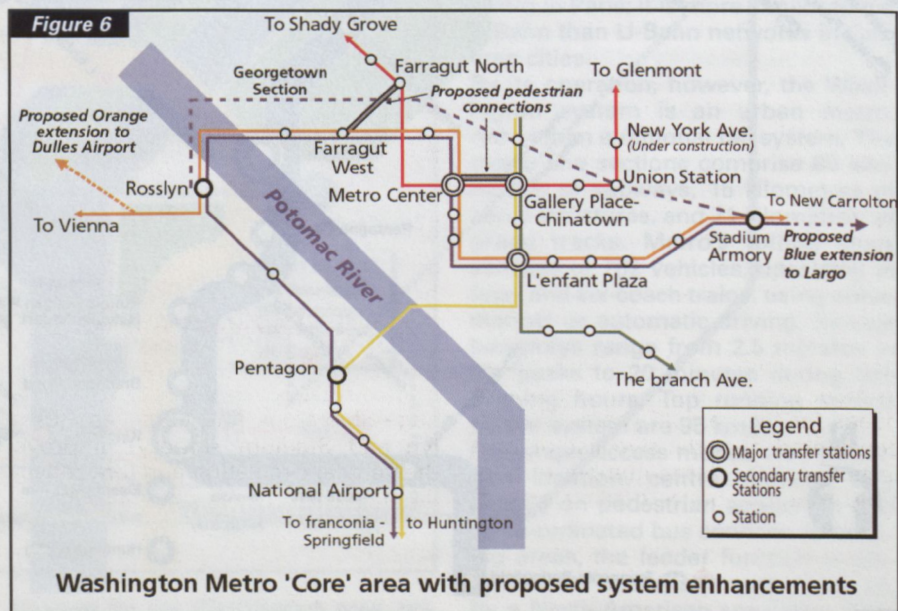
To improve train-side line capacity, all relevant elements were explored and their potential to increase capacity was assessed. These elements and the resulting upgraded line capacity are shown in Figure 4. By far the greatest potential for capacity increase, approximately 30%, is in increasing train lengths from six to eight vehicles. Station lengths are ad-

equated, but power supply systems, rolling stock, and storage and maintenance facilities need improvement to facilitate this upgrade. Another possible increase lies in increasing the present load factor, increasing the number of standees, but in many cases on relatively short distances.

Decreasing minimum headway required an analysis of two compo-

hour) over the current operation of 150 seconds. It was noted that this minimum headway was a result of long dwell times at the critical transfer stations: Metro Center, Gallery Place, and L'Enfant Plaza. Network design measures to decrease these concentrations were identified.

By introducing eight-coach trains, the present capacity would be increased to 28,800 persons per hour. This capacity, however, is still inadequate to meet the projected 2025 demand on the Orange - Blue lines trunk. If dwell times at transfer stations were decreased to allow headways of two minutes, and the load factor raised to 150 persons/carriage, the lines would carry 36,000 persons/hour. The loads would be increased, but they would still be lower than loads found on many other heavily loaded metro systems. However, this lowering of the passenger comfort could be avoided by construction of additional lines in the city centre. New lines would increase area coverage, distribute passenger transfers to more stations, thus allowing shorter headways, increased capacity and less overcrowding on the existing lines. This option has been considered, although not adopted until new funding becomes available.

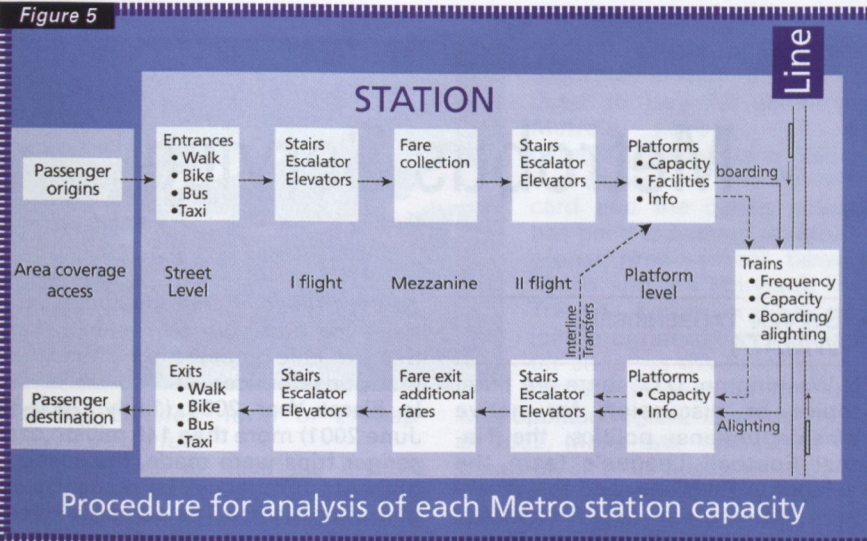


nents: minimum train separation along the line, and maximum dwell time at any station (terminal constraints were ignored as non-critical). Railsim© software was used to determine the minimum train separation; the simulation results matched field measurements. Empirical studies were also conducted to determine passenger boarding and alighting rates specific to the Metro system, from which station dwell times were calculated. The minimum headway was determined to be 135 seconds, a small improvement (two trains per

**Station capacity**, unlike line capacity which is calculated sequentially, must be computed for individual stations. The analytical procedure used in Figure 5: passenger volumes are compared with processing rates at all station components from the street to the mezzanine level, through the fare collection system, to the platform level, as well as in the exiting direction. At transfer stations, flows of transferring passengers are shown for the paths between the platforms only. In each case, the number of escalators, elevators, fare collection devices



Figure 5



and gates were inventoried and corridor and platform sizes were measured. The results of this analysis showed critical capacity shortages in many components (platform size, escalators, and fare collection) for most core stations. The situation is most critical at the major transfer stations. It should be noted that many Metro stations are extremely deep, the deepest approximately 60 metres below surface level. Functioning escalators and elevators are critical to ensuring Metro access capacity.

Also included in the core capacity analysis was a study examining the system's operating flexibility, and an evaluation of present and possible additional interline connections. Greater operating flexibility results in increased reliability, and often in higher capacity for certain lines or their sections. Furthermore, some re-routing of trains allows WMATA to provide custom-made services for frequent civic events.

#### Network enhancements new lines

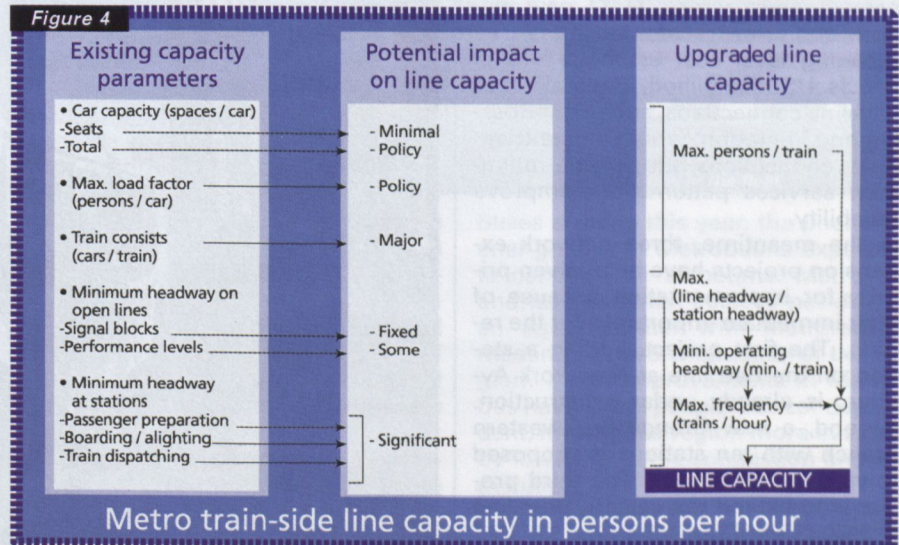
In order to meet the region's mobility needs for the next 25 years, WMATA considered an extensive list of projects. From this large number of possible system enhancements, a prelim-

inary group of projects have been developed for short-term (year 2006), medium-term (2014) and long-term (2025) implementation. Short term projects include: increase

Metro Center and Gallery Place, the two most heavily loaded transfer stations of the Red line with Blue/Orange and Green/Yellow lines, respectively; construct a pedestrian connection between these two close stations which decreases transfer volumes at all three city-centre transfer stations; re-route some Blue line trains to the Yellow line via L'Enfant Plaza, thus opening more capacity for the heavily used Orange line from the west.

For the medium term, the following projects have been given particular attention: implement demand management strategies, such as fare revisions, to encourage shifts in travel from peak to off peak periods; purchase additional rolling stock and complete introduction of eight-coach trains; construct an additional pedestrian connection between Farragut North (Red line) and Farragut West (Orange line) stations, which would reduce transfers at Metro Center station; provide 9,100 additional park-

Figure 4



the service frequency toward maximum levels, particularly on the Orange-Blue trunk line (between Rosslyn and Stadium Armory); improve the vertical circulation and fare collection capacity at core stations, such as

and-ride spaces for many suburban stations. It is expected that these improvements will be adequate to meet the passenger increases until 2014. Beyond 2014, WMATA is evaluating these long-term projects: a Blue line,

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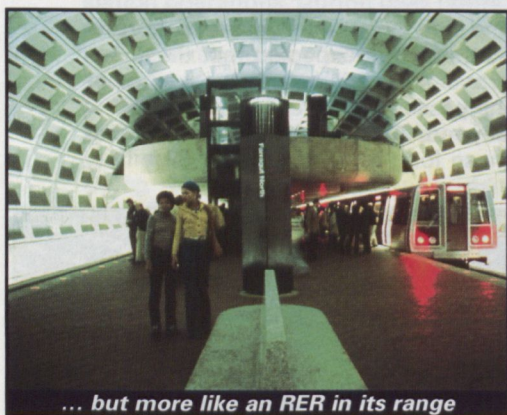




The Washington metro is urban in its operation...

designed to start from Rosslyn in Virginia, provide service to the attractive Georgetown area (initially opposed to Metro, now asking for service) through the central area to Union Station and terminating at Stadium Armory. The proposed line would unload the heaviest Blue-Orange line trunk and would better distribute passenger loads across its 11 new stations and three transfer locations. The planning level cost estimate for the line is USD6.3 billion. Several other interline connections, such as at Rosslyn and Pentagon, would create triangular connections but provide redundant services patterns and improve reliability.

In the meantime, three network expansion projects have been given priority for implementation because of their immediate importance for the region. The first project, adding a station on the Red line at New York Avenue, is already under construction. Second, a new Orange line western branch with ten stations is proposed toward Dulles Airport. The third project is to extend the eastern Blue line branch toward Largo.



... but more like an RER in its range

Figure 6 shows these recommended enhancements of the Metro system. The planned projects are intended to increase the capacity of the core, expand the system's area coverage and allow further network extensions in the growing suburbs. This comprehensive plan is expected to keep pace with the growing mobility needs of the Nation's capital. ◀

## United States

# Metrobus Service

▶ **STEVEN TAUBENKIBEL,**  
WMATA

IN Washington, D.C., there are three topics of discussion for native Washingtonians: politics, the National Football League's team the Washington Redskins, and the Washington Metropolitan Area Transit Authority, otherwise known as Metro. Most of the discussion normally centres on Metrorail, which just celebrated its 25<sup>th</sup> anniversary. However, there

creased reliability and customer convenience and comfort," stated Jack Requa, chief operating officer for Metrobus Services.

In Fiscal Year 2001 (1 July, 2000-30 June 2001) more than 145 million passenger trips were made, the second-highest number ever recorded in Metrobus history. The authority's fleet of 1,443 buses travelled more than 450 million passenger miles during the same fiscal year. The system operates 362 routes and 2,652 directional



The U-Street Shuttle

is another part of the Metro system that has an equally important role in providing transportation service: Metrobus.

The Metrobus system celebrated its 25<sup>th</sup> anniversary in February 1998. Now entering its 29th year of service, more than one billion miles of service have been operated and more than 3.50 billion passengers have used the system. Metrobus is not only the largest bus service in the D.C. metropolitan area; it is the fifth-largest nationally, based on fleet size.

In the past five years, the Metrobus system has come into its own as the fastest growing in the U.S. With the implementation of an improved fare structure, a seven-year commitment to not raise fares for bus and rail and introducing newer buses, more than 500,000 customers use Metrobus each weekday.

"Replacing some of our older buses with newer buses has greatly in-

creased reliability and customer convenience and comfort," stated Jack Requa, chief operating officer for Metrobus Services.

Recently, Metro has introduced a variety of new services and enhancements to the Metrobus system, ensuring the safety, security, comfort and ease of use for all passengers. Here are a few examples:

**COMPRESSED NATURAL GAS BUSES** - In the last year, Metro's Board of Directors authorised the purchase of 164 new compressed natural gas (CNG), low-floor buses. Along with advancing a contract to procure these buses, the Board also authorised Metro to proceed to construct a CNG fuelling facility to be located in Northeast Washington, D.C. "This decision propels Metro to the forefront with transit properties utilising newer and cleaner alternative forms of fuel, other than diesel," stated Metro Deputy General Manager, Jim Gallagher. "These new CNG buses will be added to our current fleet. The current diesel buses



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## NEW BUS SUPPLIERS FOR RATP



## Washington, D.C to improve transit